mentioned. Another appendix, on the zoological material, is principally devoted to the description of a new arachnid and of a new oligochæte annelid collected on the snow. An appendix on the rocks and minerals is for the most part a discussion of Russell's previous work, but contains the information that the outcrops near the summit of the mountain consist of typical diorite passing locally into hornblendite.

The ascent of Mount St. Elias was an achievement worthy of a prince, and this handsome volume is worthy of the achievement. Beautifully printed, magnificently illustrated and tastefully bound, it reflects credit upon all concerned in its production. But (alas! the inevitable but!) it has no index. G. W. L.

A HYDRODYNAMICAL THEORY OF ACTION AT A DISTANCE.

Vorlesungen über hydrodynamische Fernkräfte nach C. A. Bjerknes' Theorie. Von V. Bjerknes. Band i. Pp. 338; with 40 figures. (Leipzig: Johann Ambrosius Barth, 1900.)

THEORIES of matter—or should we not rather call them theories of *force*, since, in "explaining" the properties of matter, we are mainly concerned with those manifestations which we say are due to "force"—naturally fall into two distinct classes. The first class includes those hypotheses which regard continuous matter as being built up of discrete particles, and the direct action of finite portions of matter as being due to action at a distance of these particles. The second class includes those hypotheses which regard these particles as singularities in a continuous medium, and which attribute their action at a distance to the direct agency of the medium. In a certain sense, these two theories are reciprocal. In both, certain attributes are localised at points, and it is necessary to bridge over the distance between these points. According to the first hypothesis, a field of force pervades the intervening gaps; according to the second, they are filled with a distribution of mass. The belief that both hypotheses are possible, enables us to imagine that there may be no limit to the smallness of the scale on which Nature conducts her operations, the phenomena occurring in any region being made to depend in their turn on others occurring in the far more minute regions which are regarded as constituting its ultimate elements, and these elements being in turn capable of further subdivision, and so on indefinitely.

In 1852, Lejeune-Dirichlet, being unacquainted with the works of Green and Stokes on this subject, published a paper containing the solution of the problem of the motion of a sphere in an incompressible fluid. In a course of lectures given at Göttingen in 1855–56, Dirichlet gave the corresponding solution for a sphere fixed in a steady current, and invited his pupils to attempt the solution for an ellipsoid. Among these pupils were Schering, who solved the problem, and C. A. Bjerknes, who gave a generalisation for space of n dimensions. At this time the doctrine of action at a distance may have been said to be at its zenith, and Göttingen had given birth only a few years previously to the last brilliant product of that doctrine, Weber's Law. As a foreigner, Bjerknes was, however, less influenced by the views then prevailing in the Göttingen school, and a volume of Euler's correspondence falling into his hands caused him to oppose the doctrine of action at a distance. A fresh light was thrown on the hypothesis of a continuous all-pervading medium by Dirichlet's discovery that a sphere moving in an incompressible perfect fluid experiences no retardation from the fluid, and an impetus was given to Bjerknes to develop Dirichlet's investigations in a direction widely differing from anything then contemplated by his professor.

From the effects of purely translational motions of two spheres, Bjerknes was led on to consider the mutual actions of two pulsating spheres, and discovered that such spheres attract or repel one another according as their phases are the same or opposite, the law of force being that of the inverse square. Bjerknes found, moreover, that the expressions for the forces acting on a sphere moving in liquid consisted of two terms, which he distinguished as "inductional forces" and "energy forces," a result which he arrived at by considering the expressions for the pressures on the spheres, but which might have been found more readily had Thomson and Tait's application of Hamilton's principle been then known to him. About 1875, Bjerknes published a paper in which he established the hydrodynamical law of action and reaction, and the analogy with electric and magnetic action at a distance; and in the following year he gave an independent investigation based on the Hamiltonian principle.

From 1875 onwards, Bjerknes appears to have occupied himself chiefly with the terms of lowest order in the expressions for the forces; and in 1878 he discovered the law of rotation for oscillating spheres. Since then he seems to have devoted his attention mainly to electric and magnetic analogies, and in the middle of his eightieth year he completed the discussion of the "inductional forces," and by this means pushed the analogy between hydrodynamic action at a distance and electromagnetic phenomena as far as it could be pushed without departing from the fundamental hypotheses.

A complete account of these investigations was never published, and it remained for his son, Prof. V. Bjerknes, to embody them in the present volume. For three years Prof. V. Bjerknes has delivered courses of lectures on the subject at the University of Stockholm, and the book is practically based on these lectures. It is divided into four parts: the first, an introductory part, dealing with the general principles of vector fields and hydrodynamical equations; the second, dealing with the motion of the liquid surrounding a system of moving spheres treated from a kinematical standpoint; the third, dealing with the influence of the pressures on the motion of the spheres themselves; and the fourth, with the theory of apparent actions at a distance, of hydrodynamical o[illegible] In the second part, the diagrams of the stream lines due to a moving, oscillating or pulsating sphere in various fields of force are noticeable for their elegance.

It is to be wished that the courses of lectures which Prof. V. Bjerknes delivered on the work of his father could be taken as models of what university lectures should be, for the development of a theory such as the present affords an excellent and not difficult insight into

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the methods of mathematical analysis. So long as our English university colleges are, to a great extent, in the hands of oligarchies, who attach more importance to such trifles as the handwriting and spelling of matriculation or medical preliminary students than to higher scientific study, such courses of training will only be accessible to those who seek them in countries more enlightened in the matter of scientific education than Great Britain. We can readily imagine that Bjerknes' theories may find their way into many transatlantic universities among the "classics of science." They have, indeed, no small claim to be regarded as classical. It is true, as Prof. V. Bjerknes points out, that his father's and Kirchhoff's work in several cases somewhat overlapped, but it would appear that in developing the theory of motion of spheres in liquids as a basis for explaining the properties of matter, Bjerknes stood entirely on ground of his own making. Other theories involving the conception of a continuous medium have sprung up; we have had the vortex-atom theory before us, and we now find it necessary to postulate the existence of an ether, whose attributes resemble those of an elastic solid rather than a fluid. At the present time few will regard the hypothesis of pulsating spheres as of more than classical interest. As having been first developed in the face of a prevalent belief in the doctrine of action at a distance, and as ingenious methods of replacing this action at a distance by the action of an intervening medium, the application of the term "classical" to these investigations of C. A. Bjerknes may not be altogether without justification.

G. H. Bryan.

PHOTO-MICROGRAPHY.

Photo-micrography. By Dr. Edmund J. Spitta. Pp. xi + 163. (London: The Scientific Press, Ltd., 1899.)

A QUARTER of a century has now elapsed since the renaissance of the art and science of photo-micrography. Up to that time much of the best work in this direction was accomplished in America by Lieut.-Colonel Woodward, of Washington, whose successful photographs of diatoms excited the admiration of all microscopists who saw in his productions the faithful delineations of those "markings" on them, on which many hours of microscopical manipulation had been spent in bringing their delicate tracery to a correct definition. From that time to the present the fascination of transferring the minutest details of histological and biological science to the photographic plate has found many ardent votaries, with the result of improved apparatus and lenses corrected to such a degree of accuracy for this work that sharp and well-defined images can now be obtained in a manner that would have been a boon and a revelation to workers twenty-five years ago.

Amongst the latest exponents of this branch of microscopical science we must name that of the author of the book under consideration.

Dr. Spitta in this work on photo-micrography has dealt with the subject very fully and from a scientific standpoint, so that the student who takes up this branch of the photographic art is thoroughly furnished with all the information necessary to the accomplishment of perfect work, leaving, however, only that amount of *personal experience* to be obtained and which will be demanded of every one who first embarks on this art, and without which he is liable to be landed in many difficulties.

In Chapter i. the author deals with illuminants, a by no means unimportant point for consideration; for although we have several good illuminants for low power work, it is when we come to work with the highest power objectives that either the lime-light or that of the electric arc lamp must be employed to produce the best possible results. These lights are not always readily accessible; but as the aspiring student most probably will try his 'prentice hand on low power work, the single wick lamp burning the best paraffin oil will furnish him with a light sufficiently rich in actinic rays that, provided the proper length of exposure be given, will result in a very successful negative. Dr. Spitta in Chapter ii. proceeds to give directions for obtaining photo-micrographs by low power objectives, dealing with this in such a lucid manner that the student who closely follows his clear description cannot fail in being rewarded by satisfactory results, being assisted in his work by algebraical formulæ and illustrations of simple but effective apparatus.

Chapter iii. deals with medium power photo-micrography, and contains some very necessary cautions relative to the avoidance of vibrations in the apparatus, for, as the author observes, "when photographing at 1000 diameters, 1/1000 of an inch shake in the specimen makes a shift of one inch in the photographic plate," or he might have said in the photographic *image*; therefore the absolute necessity of the most perfect stability, not only in the apparatus but even in the studio, can be readily understood and provided for—even a heavy tread on the floor of an adjoining room being sufficient to disturb the steadiness of the optical arrangement. Dr. Spitta describes different methods whereby this difficulty may be overcome. Allowance must also be made for the expansion of the metal of the microscope from the heat of the illuminant, for even in low power work, say of 250 diameters, the heat from the oil lamp must not be considered a negligible quantity, and must be considered so far that no photographic exposure should be attempted till the metal has had time to become fully expanded.

Chapter iv. is overloaded with woodcuts of different makes of microscopes valuable as affording the student a choice of various instruments, but by no means necessary to his work, as any one of these is sufficient for attaining good medium power work. This chapter also deals with the subject of lenses and eyepieces and the accessory fittings of the microscope generally; but there is one point that must have the greatest attention, and that is the fine adjustment, and Dr. Spitta does well in laying great stress upon its importance; nothing is more embarrassing to the operator, when perhaps everything else in the apparatus is working well, to find that the fine adjustment by which he hopes to obtain that sharp definition without which his work is valueless, is altogether useless from faulty construction, and Dr. Spitta describes the various forms of this all-important addition to the photo-micrographic installation.

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